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STANFORD CENTER FOR RESEARCH AND DEVELOPMENT IN TEACHING

Revised Research Memorandum No. 11

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Abstract

Forty fifth- and sixth-graders, matched on sex and measures of test anxiety, defensiveness, and I.Q., were divided into two groups, each of which solved Porteus maze tasks and a marble puzzle, with and without memory support, respectively. An anxiety x memory support interaction occurred in the number of errors made prior to solving the marble puzzle, as predicted, but did not occur in the Porteus maze task. It was suggested that anxiety's interference with short-term memory could be offset by a variety of external aids such as diagrams or notational systems which problem solvers could be taught to use.

THE RELATION BETWEEN TEST ANXIETY AND NEED FOR MEMORY SUPPORT IN PROBLEM SOLVING [1,2]

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It has long been recognized that anxiety interferes with certain cognitive processes (Freud, 1925; Taylor and Spence, 1952; Farber and Spence, 1953; Spielberger, 1967). Moreover, test anxiety has been found to have a cumulative debilitating effect on I.Q. measures and school performance over the elementary school years (Sarason, Davidson, Lighthall, Waite, and Ruebush, 1960; Hill and Sarason, 1966). Further, Spielberger (1962) found that high anxious students were nearly four times as likely as low anxious students to drop out of college on account of academic failure. However, despite increasing concern about the effects of anxiety on intellectual development and performance, no concerted research program has been undertaken to discover and develop new learning environments which minimize the debilitating effects of anxiety or extinguish the characteristic interfering (anxious) responses.

This lack of a comprehensive confrontation of the problem is not surprising in view of the host of conceptual and methodological problems which confront the researcher who wishes to discover constructive solutions to the problem of test anxiety. The various currently used ways of reducing

anxiety (e.g., behavior therapy, removal of threatening cues, pharmacological treatment) are not entirely appropriate for improving the test performance of test anxious persons. For example, the first two approaches involve reduction of motivation and of the salience of task-relevant cues. However, both motivation and attention to task-relevant cues are required for effective problem solving. The processes affected by drugs are simply not yet sufficiently well understood to warrant drug use for this purpose. In addition to the inappropriateness of established anxiety-reducation techniques, are certain problems of definition and measurement which have been discussed elsewhere (Sieber 1968), and are summarized as follows. 1) As yet, precise measures of level and change in level of test anxiety have not been published. Hence, validating measures for experimental procedures purporting to reduce anxiety are unsatisfactory. 2) The nature of test anxiety, its causes and its manifestations, are not clearly defined. 3) There is no clear conception of what it would be desirable to do about test anxiety--i.e., there is no comprehensive rationale for any experimental intervention designed to somehow "solve the problem of test anxiety". To elaborate further on this third problem, it is not clear that anxiety, per se, can be eliminated in evaluative situations. It is not even clear what comprises the "anxiety" that it might be desirable to eliminate--would this consist of consciously perceived feelings of apprehension, or certain overt behaviors? Moreover, since anxiety seems to facilitate rather than debilitate some intellective processes under certain conditions (Waite, 1959, Spielberger,

1966), it might not be desirable to eliminate anxiety even if a feasible means of doing so were discovered.

In the present experiment, these problems were circumvented by use of a paradigm suggested by Sieber (1968), which focuses not on anxiety, but on the effects of anxiety upon various cognitive processes. The aim of research which utilizes this paradigm is to examine how certain intellective processes are affected by anxiety, and how learning environments may be re-designed so that the facilitating effects of anxiety may be capitalized upon and the interfering effects of anxiety not brought into play. This paradigm is concerned neither with a comprehensive definition of test anxiety, nor with the reduction of test anxiety. Rather, it is concerned with the effects of test anxiety on task-relevant cognitive processes and with the experimental augmentation of those processes which are both debilitated by anxiety and are necessary for task performance. The dependent measures of such research are cognitive mediating process variables (e.g., ability to remember details of a problem) and solution-relevant variables (e.g., number of trials to solution).

A cognitive process which is chosen for examination in this paradigm must meet the following criteria:

1) It must be an essential component of some model of cognitive processes in problem solving.

2) There should be reason to believe that it is affected by anxiety.

3) It must be experimentally augmentable in some way.

A cognitive process which meets these criteria could be studied as a function of anxiety in the context of performance on a task which requires that process. The task must be such that it permits experimental augmentation of that process. If high anxious persons are less able than low anxious persons to engage effectively in the selected cognitive process, and if experimental augmentation of the process results in differentially improved problem solving as a function of anxiety, then this experimental procedure will have yielded a plausible basis for inferring a causal relationship between anxiety and ability engage in that cognitive process, and a practical methodology for reducing the debilitating effects of anxiety on problem solving which requires that process.

The cognitive process investigated in the present experiment was short-term memory of alternative configurations of a set of information. By short-term memory of alternative configurations of a set of information, we mean ability to retain for a brief period both the various pieces of information relevant to the solution of a problem in the course of their being cast into alternative integrations, and ability to recall their various integrations in order that they may be compared and evaluated.

This short-term memory process meets the first criterion as it is a component of any problem which is not clearly defined, where it is the student's task to determine precisely the nature of the problem and the procedure by which it is to be solved. A mathematical problem in which a situation is stated and a solution is required, but in which the student is

not told what algorism to use, is an example of such a case. Another example is the task of reading a very complex novel, such as Crime and Punishment, and outlining the plot or describing the significance of the story. Tasks such as these require that one keep track of much material, and organize it in various ways, until a satisfactory organization is found. Inability to keep track of the details of the various integrations so that they may be compared with the selected criterion (criteria) would result in an inability to arrive at a completely adequate solution.

Perhaps all meaningful learning requires short-term retention of alternative integrations of a set of information. "Meaningful" learning, while typically not clearly defined, implies that a new body of information must somehow be organized and integrated into the fabric of one's knowledge. Selecting the appropriate integration of information from among other possible integrations would comprise another example of the use of short-term memory of alternative configurations of a set of information. It has frequently been stated in the literature that rote and simple learning are easy for anxious persons, but that complex and "meaningful" learning are difficult.

Difficulty in recalling at will, alternative integrations of information is probably underlain by some of the same processes as associative interference, the difficulty of forming associative bonds because of prior associations. The debilitating effects of anxiety on this latter process have been documented (Spielberger, Goodstein and Dahlstrom, 1958; Castaneda, Palermo, and McCandeless, 1956; Stevenson and Odom, 1965).

The second criterion is met as comparison of experiments which require exploration of various syntheses of information in order to select a single correct answer, but which vary in extent to which short-term memory processes are required, suggest that short-term memory for such information is impaired by anxiety. Waite (1959) required high and low anxious persons to solve Porteus maze tasks. He found that high anxious persons made fewer errors than low anxious persons when under little pressure to respond, and explained this result in terms of high anxious persons' greater tendency to be cautious and hence to acquire and consider more information before acting. However, high anxious persons are not more careful or accurate problem solvers in other situations in which there is little pressure to respond, when the information on which they need to operate is not available and organized for them in some external form. For example, they seek less information before making decisions, and reach decisions more rapidly (Lanzetta, 1963). Their word-association performances are more often characterized by errors of commission consisting of emitting first-available, incorrect responses (Castaneda, et.al., 1956; Stevenson and Odom, 1965). In Waite's task, all of the required information, including the nature of all alternative choice points, was permanently displayed before the subjects enabling them to keep track of the information by vicarious trial and error (VTE) with little dependence on memory. No such memory support was available in the other experimental situations.

The third criterion is met as memory support may be provided. Memory support may consist of any external memory bank, mneumonic

device, or organizing principle which could aid in the retention and alternative re-organization of information. In this experiment, memory support consisted of an external memory bank containing information from prior trials. Evidence that memory support facilitates problem solving of anxious persons would consist of an Anxiety x Memory Support interaction on performance, such that anxious persons would require more trials to solution and would be less able to recognize satisfactory solution approaches before overtly carrying them to completion without memory support than would low anxious persons under either condition, or high anxious persons, under conditions of memory support.

If an essential difference between problem solving of high and low anxious subjects under memory-taxing conditions lies in their relative ability to hold the details of alternatives in mind long enough to compare or evaluate them and thus to formulate effective solution strategies, the following predictions should be confirmed:

1) When information must be memorized before a correct strategy can be formulated, high anxious persons will make more wrong choices than low anxious persons and will less frequently recognize that a solution is erroneous during VTE.

2) Provision of memory support will reduce the difference between high and low anxious persons and frequency of wrong choices and failure to recognize errors during VTE.

METHOD

Subjects. This experiment was conducted at an elementary school in a suburban, upper-middle-class area. All fifth- and sixth-grade students were administered a modified version of the Test Anxiety Scale for Children (TASC) a few weeks earlier. Of the one hundred and seventy children who took the TASC, forty children were selected whose scores fell in the upper or lower quarters of the distribution. These children were placed in matched pairs with respect to test anxiety, I.Q., sex and general defensiveness. (See Table 1) All but four of the Ss had test anxiety scores in the upper or lower quarters, and those four scores were within two points of the quartile mark. Members of the pairs were then randomly assigned to one of two treatment groups as described below.

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Insert Table 1 about here

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Stimulus Problems. To determine the extent to which facility of short-term memory is affected by test anxiety, and thus accounts for differences between high and low test anxious children's problem solving abilities, we utilized two types of problems, each of which may be presented to Ss with or without provision of memory support.

One type of problem consisted of two sets of mazes. One of the sets contained 5 standard Porteus forms which are typically used for testing children of ages 5 through 14 (Porteus, 1950), and are the same type as those used by Waite (1959). By their nature, these mazes provide memory support; Ss may engage in VTE behavior among visible alternatives. The other set contained 5 mazes, each of which was matched for difficulty with a corresponding maze in the first set. This set of mazes was designed

specifically for this experiment such that it provided no memory support. Each maze had a series of three overlays; each successive overlay concealed a smaller portion of the maze and excluded from view the end points of several cul-de-sacs. Thus, the memory support which is present by the usual nature of the maze is removed and S is freed to recall details of the maze as earlier revealed to him or fail the test.

The other type of problem was a marble puzzle, which is simple in design but difficult in execution. It consisted of a board containing a row of 9 small evenly spaced holes, over which 4 black and 4 white marbles are placed. Figure 1 illustrates the starting position of the eight marbles. The puzzle is solved when the marbles of the two respective colors have been moved to the opposite end of the board from their starting position. Only two types of moves were allowed in the attempt to transpose the positions of the marbles: forward (i.e., toward the opposite end of the board) to an adjacent empty hole, and forward over one adjacent marble of the opposite color to an empty hole. Although there is only one sequence of 24 moves that will result in the solution, and although there are never more than two possible moves at any time, three of those junctures are considered "critical" because the correct moves are much less likely to be made there despite the fact that both possible moves are quite obvious. (Mistakes at these three crucial points accounted for all but four of the total number of errors committed by all Ss). Thus, the task is essentially one of learning to make the correct move at these three points in the sequence of required moves.

In its usual form, this task provides no memory support. Each move changes the stimulus configuration so that antecedent configurations cannot be referred to unless they were encoded and remembered. Thus, if a given sequence of moves leads to an impasse, the ability to avoid repeating that sequence depends on remembering the characteristic of the decisive move in that sequence. The version of the marble puzzle which provides memory support consists of three boards with marbles. If a mistake is made, another attempt is made on the second board, while S keeps the first board intact before him for reference in avoiding similar mistakes. The subject continues to rotate and reset the boards until the correct solution is found. With these visual aids, VTE behavior is possible and the memory of the subject is not taxed as it was in the standard marble task.

Procedure. All Ss were administered the marble puzzle without memory support followed by the standard Porteus mazes (with memory support). The purpose of giving all Ss prior experience with the standard Porteus mazes and the marble puzzle without memory support was two-fold: 1) it helped control for individual differences in prior experience with such tasks, and 2) it helped reduce the influence of variables other than short-term memory upon performance.

This procedure was followed because pretesting with subjects from the fourth grade through college had shown that the second solution was not greatly affected by the performance on the first successful trial. Half the subjects then worked on the marble puzzle with memory support, followed

by the mazes without memory support in that order; the other half of each matched pair again worked on the marble puzzle without memory support and the standard Porteus mazes. E was not aware of Ss' anxiety level, I.Q. or defensiveness scores. He did not give any form of reinforcement to Ss during the administration of the tasks. In spite of the game-like nature of the two tasks, it was not difficult to maintain a test-like atmosphere during the administration.

Ss were individually called from their classrooms by a messenger who led them to the portable classroom used as a laboratory. At this time, the messenger said to each S:

> You are going to participate in a Stanford University research project. We are going to administer problem-solving tasks to you. It is very important that you do well on these tasks.

Inside the portable classroom, S was greeted by E and introduced to the first task as follows:

> I have a test here that is designed to examine your problem-solving ability. Your task is to move the four white marbles to the right and the four black marbles to the left. We have a few rules you are to follow: you can move a marble only one hole at a time or over only one marble at a time. You cannot move the marble backwards nor can you jump the marble over another of the same color. Once you remove your hand from the marble, you cannot move the marble back.
>
> Do you understand what you are to do? What is your task? What are the rules for moving the marbles? If at any time you find that you cannot move, please try again from the beginning. You may start now.

The experimenter sat across the table from the subject and recorded data on a rating form. Data recorded included: number of errors

recognized*, and number of wrong choices made.

When S had successfully completed the marble task, he was presented with the first and easiest maze of the first Porteus maze set. The procedures recommended by Porteus (1950) were followed closely, except for the wording of the instructions:

> I want you to take your pencil and draw a line from the point marked S to the end of the maze. You must be careful not to cross any lines or touch any lines. Do not follow any paths that are blocked. Draw between the lines as carefully as you can without touching them.
>
> You may stop anywhere as long as you like; you are not being timed. Be sure not to lift your pencil from the paper until you have found your way out of the maze. Do you understand what you are to do?

Subjects were allowed a maximum of two trials for the first two mazes of the set and four trials on the remainder. Data on the number of errors recognized* and errors committed were secured by later inspection of the mazes.

Control subjects were re-administered the tasks and experimental subjects were given the modified tasks with instructions altered to account for the modifications. Similar measures were taken for these tasks.

No time limit was imposed on subjects, and no subjects were unable to reach solutions. The testing session did not last more than one hour and the time spent on any one task did not exceed twenty minutes.

*In both tasks the 'errors recognized' was a behavioral measure. In the marble task, this was defined as any incorrect move of a marble that was retracted before the hand was removed from the marble. (The rules state that removing the hand completes the move.) In the Porteus task, any line tracing that was withdrawn from a cul-de-sac just before actually entering it is considered a recognized error. The distinction is quite clear

and the time spent on any one task did not exceed twenty minutes.

RESULTS

Two (Anxiety) x 2 (Memory Support) x 2 (Sex) factorial analyses of variance were performed on the number of wrong choices made and the number of errors recognized for both the marble puzzles and the Porteus maze tasks. The anxiety and memory support cell means for these four analyses appear in Table 2; (sex differences did not approach significance and were therefore collapsed.)

The marble puzzle data confirmed most of our predictions. The anxiety x memory support interaction indicated that without memory support, high anxious Ss made more wrong choices than low anxious Ss, but when memory support was provided, low anxious Ss perfomed equally as well as without memory support, and high anxious Ss improved their level of performance to equal that of the low anxious Ss ($F = 6.80$, d.f. = 1/32 $p < .025$). Also as predicted, the low anxious Ss recognized significantly more errors before commission than high anxious Ss, ($F = 12.46$, d.f. = 1/32, $p < .01$). While data on mean errors recognized (listed in Table 2) take the predicted form, this interaction was not significant.

Insert Table 2 about here

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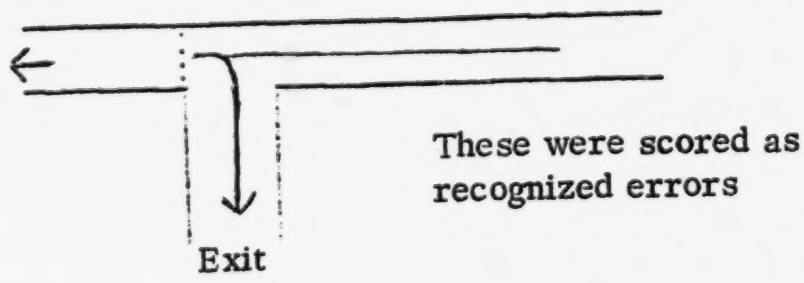
when observing the drawings. Any tracing that crosses an imaginary line that extends across the entrance to a cul-de-sac is considered an error. The recognized error closely approached this line but was retracted before crossing it.

e.g.,

cul-de-sac



The Porteus maze data did not support predictions. The only significant difference obtained was in the number of wrong choices made in relation to absence or presence of memory support. Ss made an average of 3.75 times as many errors without memory support as with memory support, indicating that all Ss found the overlaid mazes far more difficult than the standard Porteus mazes. Just as in the marble task, high and low anxious Ss did equally well when memory support was provided; in the case of the maze task, however, this is not a remarkable finding in view of the fact that the two groups did not differ when memory support was removed. This later result may have been because the memory burden imposed by that task was even too great for low anxious Ss to handle. The failure of the Porteus maze task to discriminate between high and low anxious Ss is noteworthy in that this finding is counter to the results obtained by Waite (1959).

DISCUSSION

The present experiment supported the hypothesis that anxiety interferes with short-term memory, making it difficult for anxious persons to engage in VTE when this must be done on the basis of remembered information. Moreover, when memory support was provided, anxious persons took advantage of it and thereby improved their level of performance, quite possibly on account of their cautiousness or motivation to avoid failure.

The explanation of the effects of anxiety on problem solving in terms of disruption of a specific cognitive process seems more satisfactory than explanations which are expressed in terms of cautiousness, high drive, etc., since the latter explanations fail to specify which cognitive processes are affected, or how these effects may be modified. Far from disagreeing with these explanations, however, we wish to discover whether these anxiety-related differences may not be explained at a cognitive as well as an affective or motivational level, and whether learning environments may be so re-arranged that the motivational concomitants of anxiety may be used to advantage.

It should be emphasized that in this experiment all Ss had completed a set of trials which terminated at the first correct performance of the marble puzzle and Porteus mazes, prior to the set of trials on which these data were collected. This procedure served the dual purpose of controlling for prior experience in these tasks, and controlling for some other variables

which could otherwise have possibly accounted for success (e.g., having the correct alternative in one's response repertory, understanding the task rules, or believing that a solution really exists). Hence, one of the major determiners of success in these tasks was ability to recall the characteristics of those sequences of events which lead to success.

The observation of inability to utilize previously learned complex response sequences under conditions of anxiety is not new to the psychological literature (Frick, 1956). However, the pinpointing of a specific cognitive process that is affected by anxiety, and the development of a method for reducing those debilitating effects is a new, and apparently generalizable finding; it seems reasonable to speculate that high anxious persons could benefit by learning to use a variety of external aids such as diagrams or notational systems. Watson (1967) has found that the more internal one's appraised locus of control, the more anxiety facilitates performance. Accordingly, high anxious persons who have learned to use memory aids, thus gaining greater control of their reinforcers, may begin to find anxiety serving to increase vigilance and motivation to produce fruitful ideas, rather than producing debilitating fear.

If performance were improved in this way, debilitating anxiety may be so reduced that reliance on external memory aid may be decreased. Having a repertory of external memory aids such as notational systems may allay anxiety to the extent that arousal level falls below the point at which it interferes with intellectual functioning. Moreover, mneumonic

aids and other information coding strategies may be successfully developed, permitting efficient information processing without constant resort to external aids.

It should be emphasized, of course, that memory support is not the only form of structure required by anxious persons in complex, unstructured situations. The marble puzzle presented a limited number of moves, the discovery of which require little imagination; moreover, the execution of this solution is not very complex. In some problem solving situations, however, choice alternatives are not obviously suggested by the problem itself (e.g., as in Luchins' (1942) water jar problem, or Maltzman's (1955) Unusual Uses Test). In such cases, high anxious persons may have difficulty generating alternatives, as Spence and Spence's model (1966) implies. Some means of increasing ideational fluency may constitute successful treatment in this case. In other kinds of problems, the correct solution strategy is a multi-staged one; some intrinsic structure of the problem must be recognized and at each subgoal the required sets of behaviors must be learned, then the correct sequence of these components must be integrated. In addition to learning to use notational systems to help keep track of the results of his planning and testing, the anxious person may also need some training and experience in the actual formation and testing of plans.

Task analyses of various types of problems on which high and low anxious persons perform differently may indicate a variety of different kinds of treatments which will improve problem solving performance of high anxious persons.

Table 1. Description of the sample by anxiety, defensiveness, I.Q., and sex.

	High Anxious				Low Anxious			
	Boys		Girls		Boys		Girls	
	M	SD	M	SD	M	SD	M	SD
Mean Anxiety	15.1	1.9	17.3	1.7	1.3	.7	2.8	1.4
Mean I.Q.	112.8	12.5	114.8	14.3	113.2	10.7	116.1	10.8
Mean Defensiveness	10.4	2.6	9.9	1.10	8.8	1.5	7.7	2.5

Table 2. Mean of wrong choices and mean errors recognized by high and low anxious Ss with and without memory support in the Porteus maze and the marble puzzle.

	Marble Puzzle				Porteus Maze			
	Wrong Choices		Errors Rec.		Wrong Choices		Errors Recognized	
	M	SD	M	SD	M	SD	M	SD
High Anx.								
With Memory Support	3.0	1.7	0.3	0.1	2.7	0.8	0.9	.5
W/O Memory Support	6.9	2.8	0.0	0.0	7.9	1.6	0.8	.4
Low Anx.								
With Memory Support	3.3	2.4	0.7	.2	1.3	0.4	2.0	.8
W/O Memory Support	3.1	2.1	0.6	.4	7.1	1.9	0.7	.5

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FOOTNOTES

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